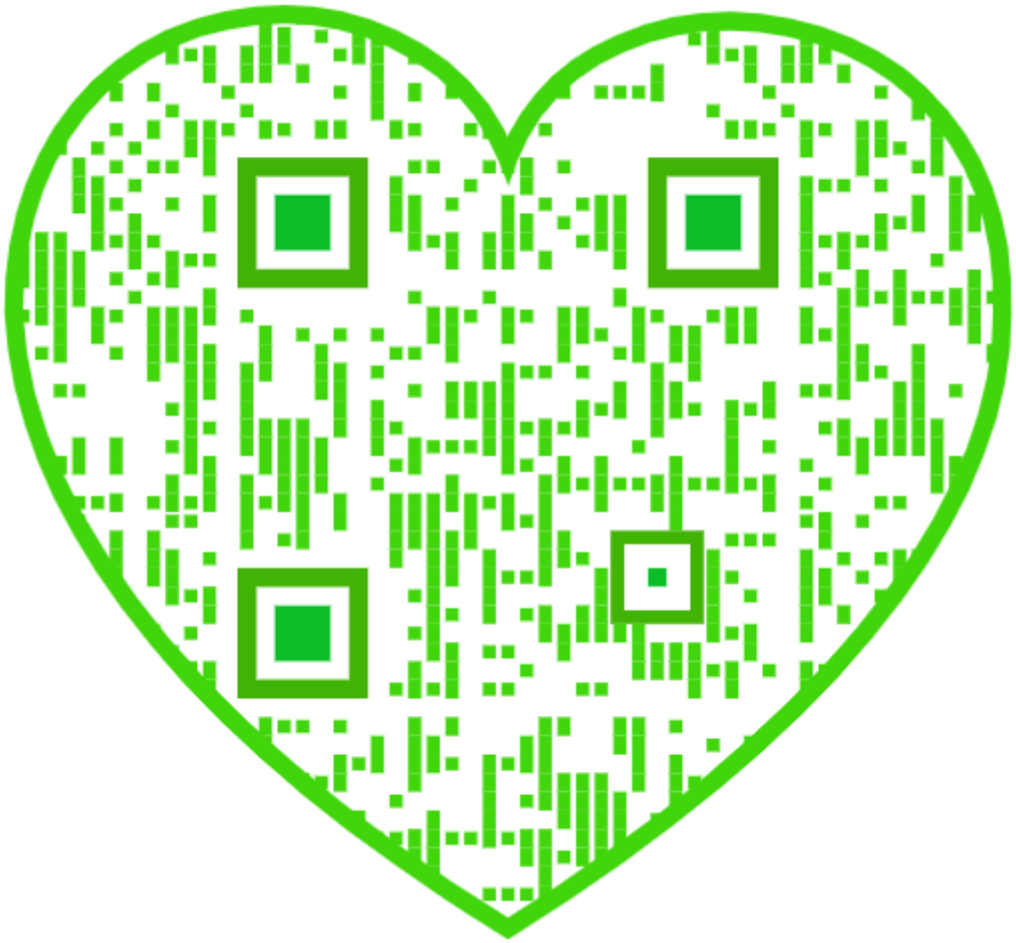
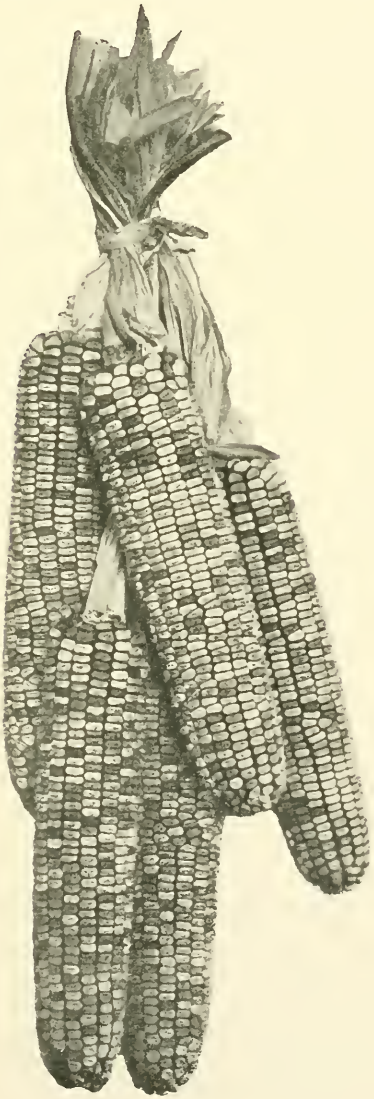


Bulletin 273 January, 1926

Connecticut Agricultural Experiment Station
New Haven, Connecticut

Crossed Corn



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Connecticut Agricultural Experiment Station
New Haven, Connecticut

CROSSED CORN

D. F. JONES
P. C. MANGELSDORF

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January, 1926

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CROSSED CORN

D. F. Jones and P. C. Mangelsdorf.

Vigorous, sturdy plants, a good sound ear on every stalk, no weak and spindling plants, few nubbins or moldy ears. These are some of the outstanding characteristics of crossed corn. It is all these desirable features combined that enable this new kind of corn to outyield the old standard varieties, year after year, and under all sorts of conditions.

Crossing two distinct types of animals or of plants almost always causes an increase in vigor. This has long been known and used in the production of mules, sterile hybrids of the horse and the ass. Swine breeders often utilize the beneficial effects of hybrid vigor by crossing different breeds of pigs, feeding for market the hybrid offspring but not breeding from them.

The same principle can be used in increasing the yield of corn and the Connecticut Agricultural Experiment Station has been working for many years to find the best methods of utilizing hybrid vigor and to produce strains of corn for crossing that give high yields adapted to the cultural and market requirements of this region.

Several promising types of crossed corn have now been produced, of which stock seed is available for seed growing. Other types are now being developed to meet different requirements and these will soon be available for distribution.

The uniform production from every plant, though the most important feature, is only one of the desirable characteristics of crossed corn. The ears are more even in size and shape, there are fewer nubbins, poorly developed ears and moldy corn. Many combinations show appreciably less smut and root rot infection. The stalks themselves are sturdy and strong and stand up when other plants are laid low by wind and rain. In time of tasseling and silking the crossed plants are far more even than ordinary varieties and in ripening there is the same remarkable uniformity.

In crossed sweet corn this uniformity in time of ripening is a very valuable feature for the market gardener or canner. It enables the grower to harvest his crop at one time and have practically all of the ears ready to be picked. This results in a better quality of canned or table corn, because fewer immature and over-ripe ears are included.

The uniform size of the ears is also particularly desirable in the case of sweet corn. It makes for a more attractive product and is a feature that appeals especially to the restaurant trade.

SEED SELECTION.

The uniformity of crossed corn, its evenness in ripening, its increased productiveness, the greater freedom from disease, cannot be obtained by any of the usual methods of seed selection in naturally-pollinated fields of corn.

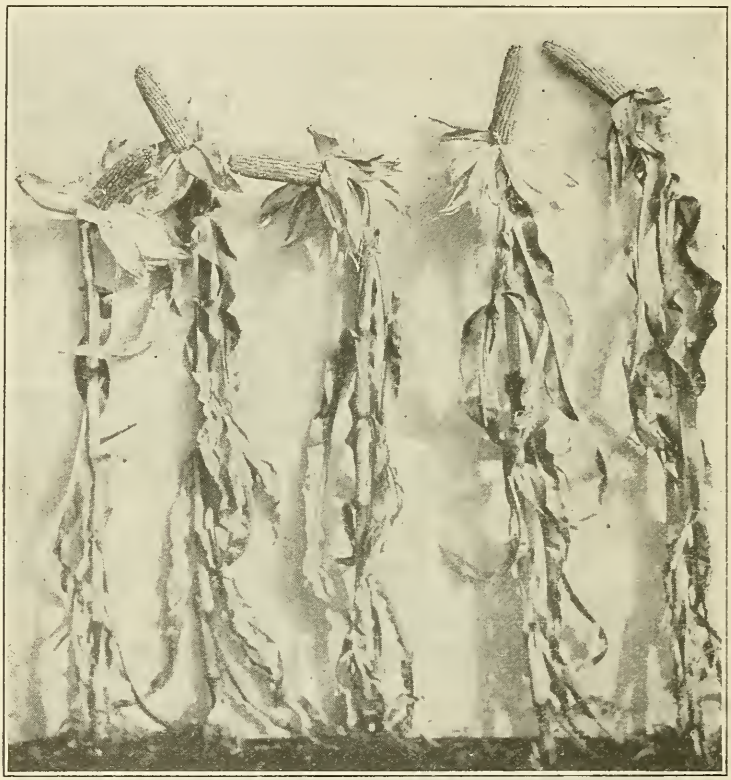


FIG. 1.—Vigorous, sturdy plants with a good ear on every stalk are characteristic of crossed corn.

One may go through a field or crib of corn, picking out the largest and finest ears, discarding all poorly filled and moldy ears and keeping only the one best ear out of every thousand, and yet these choice specimens do not reproduce their excellence; they do not "breed true." No matter how fine in appearance are the ears which are planted, they always give many weak plants and non-producers.

The failure of the finest ears to reproduce themselves has several causes. It is due, in part, to the fact that many of the best

ears are good, not because of their heredity but because of the especially favorable situation in which they grew. It is solely

FIG. 2.—In size and shape of ear and in time of ripening there is a remarkable uniformity.

their environment that has made them better than the average and the effects of environment, we now know, can not be passed on to later generations.

The main reason, however, that the selected ears do not breed true lies in the fact that the pollen which produced their seeds came from all sorts of plants. Every silk must receive pollen in order for a seed to develop. The pollen is shed by the tassels and good, poor and indifferent plants alike send their pollen into the air where it is mixed by the wind and carried to all parts of the corn field. The choicest ear in the entire field has received part of its pollen from some of the poorest neighbors.

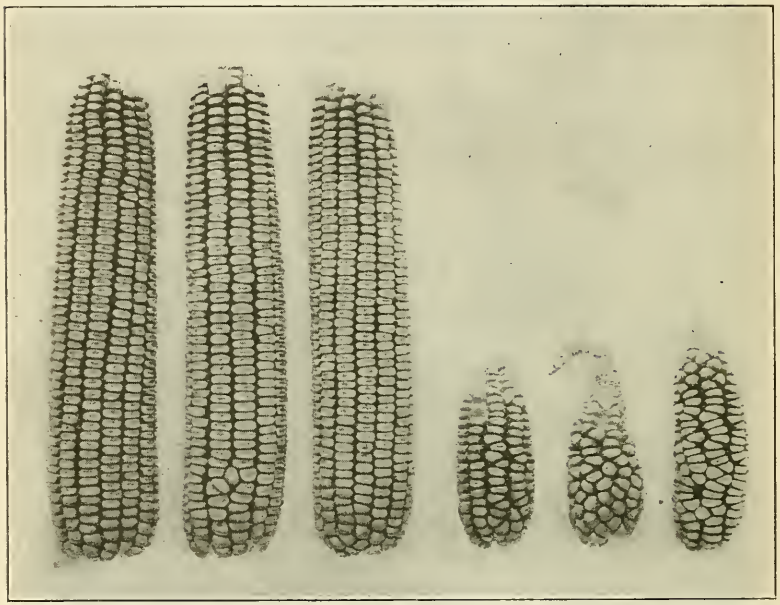


FIG. 3.—The plants grown from the small ears were just as large and the yield of shelled grain was the same as from the large seed ears.

This constant inter-crossing and hereditary mixing going on in every corn field has brought about a condition whereby every plant is a hybrid of greater or less degree of complexity and the offspring of hybrids are usually diverse and seldom like their parents. Moreover, corn has been naturally crossed in this way for countless years and is dependent upon hybrid vigor to produce its largest yield.

In spite of the natural crossing which is constantly going on, it is possible by ordinary field selection, patiently practiced, year after year, to bring about an improvement in certain respects. By saving for seed only the ears from the earliest ripening plants one may in time develop a variety that will mature somewhat

earlier. By choosing plants with many ears, the average number of ears per stalk can be gradually increased. Noticeable changes can be made in the number of rows of grain on the ear, the size and shape of the ear or the type of kernel.

Selection of this kind is usually made with some definite aim of adapting the variety more perfectly to the purpose for which it is grown. Such alterations are seldom accompanied by any increase of yield and often, particularly where extreme earliness is sought, productiveness is lowered.

Tests carried out at many places have shown that the prize winning ears at the corn shows often yield no more than unselected ears that are much less desirable in appearance. This fact is brought out in the accompanying illustration. Plants grown from the nubbins at the right were just as strong as those produced by the good ears shown on the left. The ears were fully as large and the yield of shelled corn was exactly the same.

In this case the difference in appearance of the two lots of seed ears was not due to heredity but merely to the conditions in the field in which they grew, the one in a good situation, the other in a poor one.

THE EAR-TO-ROW METHOD OF SELECTION.

When the seed from a number of ears of corn are planted separately, each in a row by itself, some lots grow better and yield considerably more than others. It was formerly thought that by selecting seed from the high producing rows or planting the remaining seed from the best yielding mother ears, and continuing this process from year to year, an increase in yield could be obtained. A marked increase in yield is sometimes obtained the first year or two but extensive tests have shown that the differences are not permanent and that in later generations the yield from the originally high producers is no more than that obtained from the unselected seed.

The failure of the high producing ears to maintain their increased yields is probably due to their hybrid composition. They split up and lose vigor in later generations. Selection towards a single type also brings about a certain amount of inbreeding which always weakens the plants.

HYBRID VIGOR.

Crossing somewhat different but related forms of plants or animals results in greater growth, the offspring often being better than either parent. Blue-gray cattle have long been used for beef in Scotland. They are the result of crossing a white Shorthorn bull and black Galloway or Angus cows. The large growth,

early maturity and fine beef quality has given this breed cross an enviable reputation whereever beef cattle are raised.

The Carolina poplar is a thrifty, fast-growing tree that succeeds well in nearly all parts of the country. It is considered to be a

FIG. 4.—Two dwarf types of corn give an astonishing result when crossed.

natural hybrid between the Cottonwood of our western plains and the European Black poplar. A valuable feature of this tree is the ease with which it can be grown from cuttings. Its vigorous nature is thus easily maintained while at the same time the trees are multiplied in numbers.

Hybrid vigor is usually responsible for part of the value of most vegetatively propagated plants. As long as they are not

reproduced from seeds the stimulus to increased growth is maintained undiminished. In naturally cross-pollinated plants it is necessary to keep up a constant intercrossing in order to maintain full vigor.

The corn plant is so constructed with its tassel, the pollen-bearing structure, at the top of the stalk, that it can be easily detasseled before pollen is shed, thereby entirely preventing self-fertilization. Fifty years ago a method was outlined whereby two varieties of corn could be crossed by planting them in alternat-

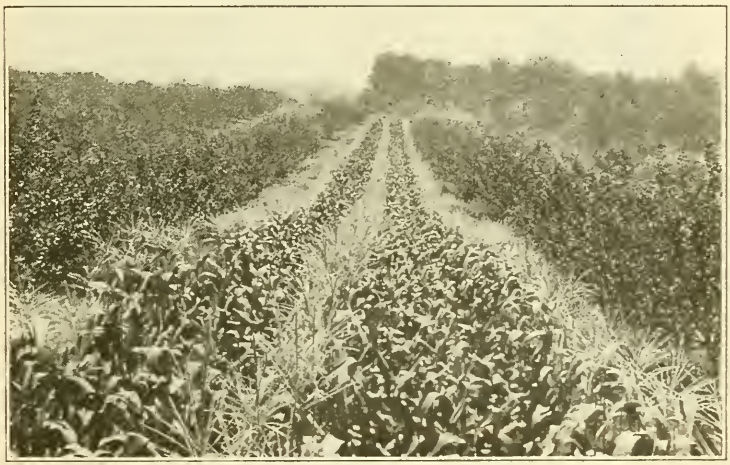


FIG. 5.—The corn plant is so constructed that it can easily be crossed by planting in alternating rows and detasseling all of the plants of one kind before pollen is shed.

ing rows and pulling out all the tassels of one variety before pollen is shed. All of the seeds borne on such emasculated plants must result from cross-pollination of one variety with another.

Numerous tests have shown that an increased yield often results when certain varieties of different type, such as flint and dent, are crossed. Some varieties of corn from China when crossed with native varieties have given considerably larger yields than either parent. Crossing an early variety with a late variety sometimes gives a cross-bred progeny that yields as much as the later parent and is appreciably earlier. Varieties of similar type when combined have not given much better results than either parent.

The increased yields which are obtained come only the first year after crossing. To get the benefit of hybrid vigor in plants reproduced by seeds it is necessary to make the cross each year and plant only the crossed seed. Any improvement in yield or

in other respects must be great enough to repay the extra cost of producing seed in this way. Variety crosses, while better than their parental stocks in some cases, have not, apparently, offered sufficient improvement to induce corn growers to make a practical application of this method.

FIG. 6.—The result of seven generations of inbreeding.

INBREEDING BEFORE CROSSING.

A larger increase in yield together with a much greater uniformity and fixity of type is obtained by first inbreeding corn by artificial hand pollination for several years and then crossing two different inbred strains. This is shown in the accompanying illustration. A variety of Leaming which yielded 96 bushels per acre was inbred, that is, the silks were artificially pollinated with pollen from the same plants. After five years of inbreeding two strains, one of which had been reduced in yield to 32 bushels per acre, the other to 20 bushels, were crossed. The first generation cross of these two low yielding, inbred strains produced 115 bushels, an increase of twenty per cent over the original variety, under the same conditions. Not only did this hybrid exceed the original variety by twenty per cent in yield but the corn was of better quality. The ears were all closely alike in size and shape and all matured at practically the same time. Every stalk bore a good ear and there were fewer moldy ears, nubbins and less soft corn.

Here is a marked improvement secured by crossing. Unfortunately this particular cross and many other combinations made in the early years of these experiments were not well adapted to Connecticut conditions. The plants ripened too late to make a satisfactory corn for husking and the stalks were not large enough to make a good silage variety. Also the low yields and poor quality of the inbred strains made it practically impossible to produce crossed seed in quantity and at a price that would justify its use.

At the present time every effort is being made at this station and throughout the corn-growing states to produce inbred strains that

FIG. 7.—The two inbred strains were derived from the variety on the left and gave the result on the right when crossed—115 bushels per acre.

will give hybrid combinations well adapted to the local needs and which will be themselves sufficiently vigorous and productive to make the growing of crossed seed commercially profitable. Other methods of utilizing inbred strains of corn are being developed.

Crossed corn seed has now been grown in Connecticut five years and tested long enough to show its possibilities. Two crosses of inbred strains outyielded all varieties in the Iowa corn yield contest in 1924 in the south central section. One of the inbred strains used in one of these crosses was developed at this station.

A combination of four inbred strains known as Double Crossed Burr-Leaming has been tested for five years in comparison with the highest yielding varieties grown in this part of the country with the following results:

	Bushels of shelled corn per acre					
Highest Yielding Varieties	1918	1919	1920	1921	1922	Average
D. C. Burr-Leaming	116	88	55	95	63	83
Beardsley's Leaming	96	54	51	85	48	67
Luce's Favorite	..	79	38	81	50	62
Webber's Dent	81	62	57	73	49	64
Northern White Dent ..	84	75	32	87	..	69
Century Dent	68	51	55	77	67	64

FIG. 8.—The uniform production of a good ear from every stalk gives high yields.

FIG. 9.—Double Crossed Burr-Leaming grown at Durham, Connecticut.

Double Crossed Burr-Leaming has been grown in many other parts of the state and in various places in the corn-growing districts

south and west. In most cases it has out-yielded all other varieties, the stalks have stood erect in the fields until harvest and the leaves have remained green until the ears are well glazed.

A cross of two inbred strains of sweet corn grown for canning has yielded six tons of ears per acre in comparison with three and one-half tons from Evergreen corn.

FIG. 10.—Weak golden colored plants when crossed with dwarfs give all tall and vigorous progeny.

WHAT INBREEDING DOES.

Many abnormal or freak types of corn are known, such as dwarf plants, golden plants, which lack the normal green coloring matter necessary to manufacture food, liguleless plants, with upright instead of spreading leaves, and other characters which seriously weaken the plants and reduce their ability to produce grain. These abnormalities are inherited and pure breeding strains can be maintained from year to year.

When one of these unusual types is crossed with a normal plant only normal plants are produced in the first generation but the abnormality reappears in the second generation and may be recovered and made to breed true again, showing that these weakening characters are hereditary.

When, for example, a golden-leaved, liguleless plant is crossed with a dwarf form there result in the first following generation only vigorous, tall growing, dark green plants with spreading

FIG. 11.—The second generation from the cross of golden, liguleless and dwarf. Eight different combinations of these characters are obtained.

leaves, all normal in every respect, uniformly vigorous and productive as shown in Figure 10.

Self-fertilizing these plants or allowing them to inter-pollinate gives an astonishing medley of plants in the next generation. There will be dwarf plants, golden plants and liguleless-leaved plants and some with two and even three of these abnormal characters combined in one individual. There will be some plants that are normal in all characters but very few will be as vigorous or productive as the first crossed plants.

The difference between the first and the second generation in respect to uniformity, size and productiveness is a very striking illustration of the bad effects of inbreeding. This is an extreme example but the same principle holds with naturally cross-fertilized

plants and with bisexual animals. In most cultivated plants such clear-cut abnormalities are not involved.

When any ordinary variety of corn is self-pollinated there is a noticeable reduction in size and yield and this usually continues for five or six generations. From this point on there is seldom

FIG. 12.—The descendants of a single plant after four generations of self-fertilization.

FIG. 13.—The plants within an inbred line are all closely alike but differ from every other line.

any further reduction. The plants in these generations, in any one strain, come to be all closely alike and remain fixed in their type from then on as long as they are not outcrossed to plants of different ancestry.

Every inbred strain descending from individual plants at the start is different to a greater or less extent from every other strain even though they all come from the same variety. Some are tall, others short. In color of leaves, silks and glumes, great

diversity is found and in the size and shape of the ears, time of ripening, ability to stand erect and in number and size of tillers there is marked dissimilarity. Productiveness ranges all the way from little or nothing up to a fair yield for inbred plants but no

FIG. 14.—Crossing inbred strains immediately restores vigor and productiveness.

inbred strains have been obtained which are as productive as the original variety and usually the yields are reduced to less than half and the size of the seed and quality of the grain are proportionately lowered.

Since all of the plants within an inbred line come to be closely alike it makes no difference from that point on whether the plants are self-fertilized or are allowed to inter-cross among themselves. Their size and productiveness remain the same as long as pollen from all other kinds of corn is kept away from them.

When an inbred strain is crossed with another strain from the

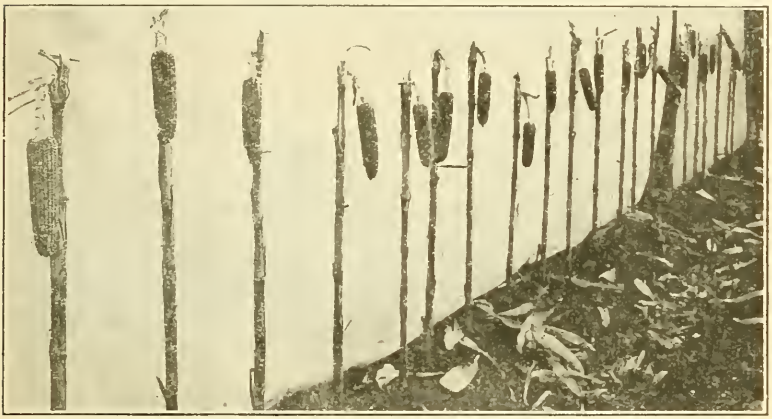


FIG. 15.—When rightly grown, crossed corn has no barren stalks or poor producers.

same or different variety there is a very great increase in size and yield in the next generation as we have already seen. In size the crossed plants are as large or larger than the original variety and in yield of grain they are often superior.

This is due apparently to the fact that the good qualities of both parents are expressed in the offspring while the weak qualities are covered over for the time being. Thus in the cross of golden, liguleless with dwarf the offspring are normal in every respect. The yellow foliage color, the upright posture of the leaves and the dwarfness of the stalk are all suppressed in this generation. What one parent lacks is supplied by the other, and conversely. Hybrid vigor seems to be a wise provision on the part of nature to enable the offspring to make the best of bad ancestry.

While most of the inbred strains do not have freak characters they are all lacking something which makes for full size and productiveness. Crossing any two strains usually brings back suffi-

cient vigor to make the plants as productive as the original variety while certain combinations are very much superior.

The greater production of crosses of inbred strains is not due so much to the large size of the ears as to the fact that every plant, if given an equal opportunity to grow, produces a good ear. Some of the ears of the original variety may be larger and finer than any produced by the hybrid but for every plant of this kind there are many stalks that have only nubbins and even some that are entirely barren.

The uniform production of an average good ear from every plant is largely responsible for the high yield of crossed corn. The even size and maturity also have distinct value in sweet corn for market gardening and canning.

HYBRID VIGOR NOT PERMANENT.

These desirable results are obtained only the first year after crossing. The second generation grown from the fine looking hybrid ears fall off in yield about 20 per cent as a general rule. While the amount of reduction may differ greatly this result always follows when hybrid corn, no matter how vigorous it may be, is used again for seed. This holds true whether the crossed plants are self-fertilized artificially or are allowed to inter-pollinate naturally.

A cross of two inbred strains grown six years averaged 101 bushels per acre. The second generation of this cross from self-pollinated first generation plants grown the same years and compared under equal conditions gave an average of 69 bushels, a decrease of more than 30 per cent.

The Nebraska Station compared the first and second generations of eight hybrid combinations during two seasons and obtained an average of 52.2 and 27.8 bushels per acre respectively for the two successive generations. The original variety from which the inbred strains were derived gave 41.7 bushels in the same period. In this case the reduction in yield from the first to the second generation is nearly 50 per cent. The second generation was grown from seed produced by inter-pollinating the first generation plants.

Not only is there this decided decrease in yield but uniformity is also lost. In size and shape of ear, height of plant and in time of ripening the second generation is even more variable than ordinary varieties.

If the second generation is again inbred the whole story of the production of inbred strains is repeated. There is a continued decrease in size and yield, as in the first period of inbreeding, and the reduction continues for about the same number of generations.

five to seven on the average, until uniformity and constancy are again reached. The inbred plants are generally no more vigorous than those of the previous inbreeding although they differ from their parental strains and from each other in minor characteristics.

In other words hybrid vigor is a transitory effect and ordinarily can not be fixed and made permanent except in plants propagated vegetatively. Varieties of fruits, vegetables and flowers that are reproduced by tubers, roots, grafts or other asexual methods of propagation owe their value to a superior combination of hereditary factors which produce the qualities desired and which also give plants a large amount of hybrid vigor. This is shown by their seedlings which are almost invariably weaker and poorer in many respects.

FIG. 16.—The first generation cross of two inbred strains will not continue to give as satisfactory results the next year. If inbred it will decline in vigor as in the first period of inbreeding.

Unfortunately from the standpoint of utilizing hybrid vigor, corn can not be reproduced in any way except by seeds. It can, however, be easily crossed. For that reason it is feasible to produce crossed seed for planting each year and grow only the first generation hybrid plants for production of sweet corn ears, grain or silage.

The additional cost of crossed seed is more easily justified for corn than for other crops because the cost of seed is a smaller item in the outlay for producing a crop of corn than for any other plant commonly grown.

SELECTION IN SELF-FERTILIZED LINES.

The character, productiveness and general value of any combination of inbred strains can not be accurately determined from the inbred strains themselves. Many strains which are weak and undesirable in their inbred condition give astonishing results when

crossed. It is necessary therefore to test out many combinations to secure the ones that have outstanding value.

Not all crosses of inbred strains are superior to the original variety and like every other good product crossed corn requires extensive selection and much thorough testing in order to obtain something of real merit.

To have a reasonable chance of securing a good combination, many inbred strains must be obtained and then tested in many combinations. This work for the present can best be done by the State Experiment Stations and the Federal Department of Agriculture until the method is more generally used. The prospect of obtaining a particularly fine combination and being able to control the stock strains from which this cross is obtained holds out an inducement to originate valuable inbred strains. Never before in agricultural history has a seedsman been able to control a valuable plant improvement.

He who invents a new machine or a new process of manufacturing can patent his product and reap a reward for his industry and inventiveness. The originator of a new and improved plant or animal ordinarily loses control of his product as soon as he sells his first seeds or breeding stock.

With crossed corn the situation is entirely changed. The seed that is sold is used to produce a superior crop of corn but this in turn can not be used for further planting and the only way the same result can be secured is to obtain seed from the original producer each year. This is an advantage that will result beneficially to both the seedsman and the one who plants the seeds. This will stimulate the production of better kinds of corn as nothing else has ever done. Larger crops of better corn will be harvested on the same acreage and with the same labor. Therefore the cost of producing a bushel of corn will be reduced.

At this Station the method of obtaining good inbred strains is as follows. A variety is chosen which has been thoroughly tested and is known to be well adapted to the purposes to which it is to be put. A large number of the best ears of this variety are selected and seed from each ear is planted in a separate row in the field. About 20 to 30 plants are grown in each row. When the plants are ready to silk out five of the best plants are self-pollinated by hand.

This is a simple process with corn. A "three pound" paper sack is placed over the ear shoot as soon as it appears and before any silks are showing. The bag is slipped over the ear shoot without being opened and is held in place with a wire paper clip. At the same time, or a day or two later, an "eight pound" bag is put over the tassel and securely fastened around the stalk at the base of the tassel, also with a wire clip.

Two or three days later, depending upon the weather, when

the silks are out about three inches beyond the tip of the ear, the tassel is bent over and shaken into the tassel bag which has been unfastened. This collects the fine yellow powder, the pollen, which is dusted over the silks. The small bag is replaced quickly over the ear and the larger tassel bag is put over this, thus guarding against breaks in the bags which will let in pollen from outside. The bags are left on until the ears are gathered in order to mark them.

Pollination can only be done when the bags are dry. Wet

Fig. 17.—Self-fertilizing corn by hand pollination.

weather or heavy dew which causes the pollen to clump together renders it unfit for use. Only a very small quantity of good pollen is needed and this should be applied as soon as possible after the silks appear.

Care is taken to avoid touching the silks with the hands and also nearby plants are pushed away so that their pollen will not fall on the silks. Hand pollination in this way insures that the ears are fertilized with pollen from the same plant. This is the closest kind of inbreeding and will have very noticeable effects on the resulting progeny.

An inbred strain starting from an ear, borne on one plant, is called a self-fertilized line. From the five hand pollinated ears made the first year in each line, three of the most desirable are

selected for planting the next year. These three progenies are grown in rows and two plants are self-pollinated by hand in each row.

FIG. 18.—Two self-fertilized lines from the same variety which differ remarkably in height.

FIG. 19.—Ability to stand erect has a basis in inheritance as these two strains were derived from the same variety and grown for fifteen years under the same conditions.

At harvest the best and second best of the three progenies are noted in each line. Two ears from the best and one from the next best are planted the following year and this system is fol-

lowed for three or four generations. At that time many of the lines are fairly well fixed in their type and are uniform.

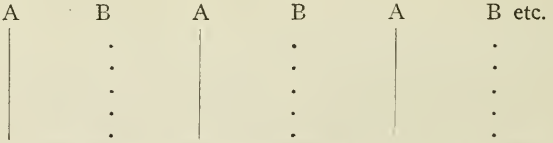
There are great differences between the several lines. Some are tall, others short and all degrees in between. Some have many tillers, others have few or none. Differences in ability to stand erect, in amount of smut damage, mold on the ears, and other characters of greater or less importance are noted.

Some lines are so unproductive that it is difficult to secure any seed from them. A number of promising strains are found that make a fairly good ear on every plant, all of the plants stand up during the season and have qualities that make them appear of value although few of them are more than half as productive as the variety started with. Nearly all of them are later in maturing than the variety at the start on account of their weakened condition. When crossed the plants grow and mature much faster and the value of the inbreeding process is at once apparent in the crossed progenies.

To obtain the best results it is necessary to test all of the best appearing inbred strains in combinations with each other. This is most easily done by hand-pollination, putting the pollen of one strain on the silks of the other and keeping a record of the strains combined.

METHODS OF PRODUCING CROSSED SEED.

When a good combination of two inbred strains, called a single cross, is once found it is a comparatively simple matter to produce crossed seed in quantity by planting the two inbred strains in alternate rows:



A = the pollen parent rows; the tassels are left on and seed from these plants is inbred and can be used for planting in a crossing plot another year.

B = the seed parent rows with all the tassels pulled out; seed from these plants gives crossed corn.

All of the plants of one kind are detasseled before any pollen is shed. This is done by pulling out or breaking off the tassel as soon as it appears above the leaves at the top of the stalks. Pollen is scattered by the wind as soon as the anthers, the tiny sacks suspended on short threads from the tassel branches, appear. These are put out first at the tip of the tassel and fresh ones come out every morning for several days. It is necessary to remove all

the tassels from all plants of one kind before the anthers can be seen. If pulled too soon the tassel sometimes breaks, leaving a portion in the plant which will later grow out and give off pollen.

If all of the tassels of one kind of plants are removed at the proper time all of the seeds produced on these plants must be cross-pollinated with the other strain. This is the seed to be used for field planting and will give vigorous and uniformly productive plants. Seed from the pollinator rows is all inter-pollinated and can be used for stock seed for planting in the crossing plot

FIG. 20.—A field in which crossed seed corn is produced. Two rows are detasseled while every third row, planted with a different lot of seed, furnishes the pollen.

next year. By maintaining two crossing plots in separate fields, detasseling one type in one field and the other type in the second field, it is possible to have inbred stock seed of both types produced each year.

Crossing can be made either way as far as the product from the crossed plants is concerned. Reciprocal crosses in corn give results that are closely, if not exactly alike. Usually, however, it is desirable for one reason or another to make the cross one way. Some strains make better seed than others while a strain that may be poorer as a seed parent may be better as a pollen parent. If this is the case a small plot of the seed parent can be

grown in a field by itself to produce stock seed for planting in the crossing plot.

It is very important to maintain the stock seed of the two inbred types free from any outcrossing with any other corn. Pollen is blown by the wind for long distances. Fields that are 500 or more feet apart and not in the line of the prevailing winds will not show much mixing especially if they are separated by a barrier of trees or other windbreaks.

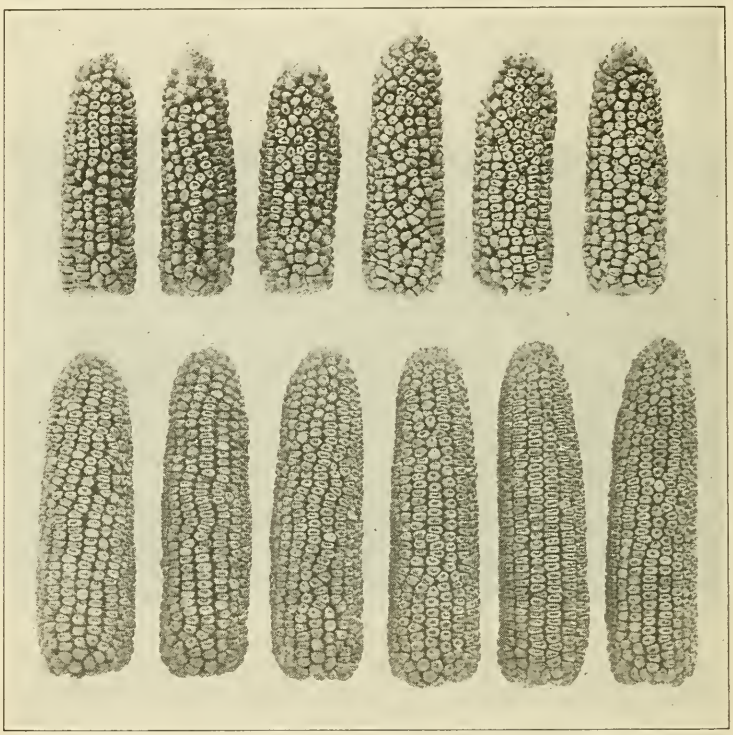


FIG. 21.—Two inbred strains showing uniformity of ear type.

Fortunately, when inbred plants are crossed with any unrelated kind of corn there is such a noticeable increase in the size of the crossed plants and change in type that is usually possible to detect such outcrosses and remove them before they produce pollen. In order to do this it is necessary to go through the crossing fields and rogue both the seed parent and pollen parent very carefully just before the tassels appear. It is best to remove or destroy the whole plant so that seed from them will not get mixed in with the stock strains.

Generally it will be found desirable to have the seed parent early in order to have the crossed seed for field planting well matured. The pollen parent can be later since pollen usually comes out well in advance of the silks. A small difference in this order will bring the two together at just the right time.

If there is much difference in time of silking and tasseling between the two parental stocks it is necessary to plant the two at different times. It is often difficult to know the right time to plant as the time of flowering varies with the season and changes unequally with different strains.

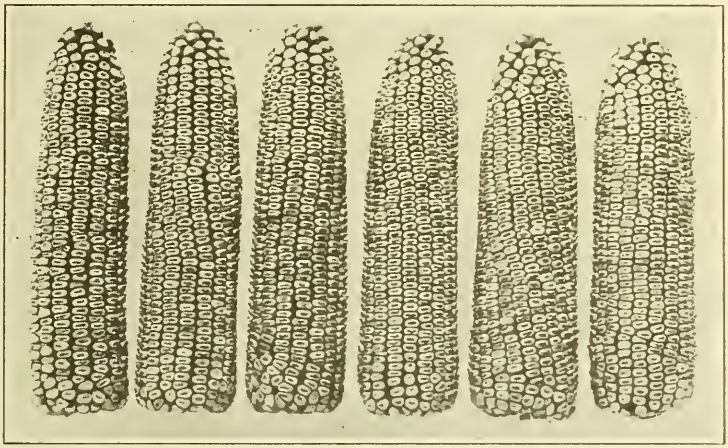


FIG. 22.—Crossing the two inbreds gives size and retains uniformity.

Two weeks difference in planting time will not make more than four or five days difference at pollinating time as the late planted corn tends to catch up with the early. However, if a dry spell or other unfavorable growing conditions intervene the later planting may not come on as fast as normally whereas the earlier planted corn may not be as much affected. For this reason it is advisable to plant the pollen parent at two different times, from ten days to two weeks apart. When the seed parent and pollen parent flower at about the same time a good plan is to plant all of the seed parent and half of the pollen parent at one time, leaving every other row of the pollinator to be planted ten days or two weeks later.

With vigorous corn it is not necessary to have the pollen-producing plants in every other row. One pollinating row to two, three or even four detasseled rows is sufficient depending on the amount

of pollen produced and the duration of the flowering period. This must be determined by trial for each particular combination and the field in which it is grown.

SINGLE CROSSES.

Hybrids produced by combining two fixed inbred strains are called single crosses and have the greatest uniformity and trueness to type in the first generation of any type of crossed corn.

FIG. 23.—Crossed corn showing evenness in height and tassel formation.

Where uniformity in size, shape and other ear characters and evenness in ripening are particularly important, as in sweet corn for market gardening and canning, it will probably be well worthwhile to use this method in spite of certain serious handicaps.

The principal difficulty of producing single crosses is the low yields and poor quality of the seed obtained from the weakened inbred plants. No inbred strains have been produced that will yield much more than half as much as the original variety when dependent upon their own pollen or pollen from other inbred strains. They also make a much smaller amount of pollen, and unless the two strains are planted at just the right time so that

pollen will be given out as soon as the silks appear, and continue until all the silks are out, the amount of crossed seed produced will be very low.

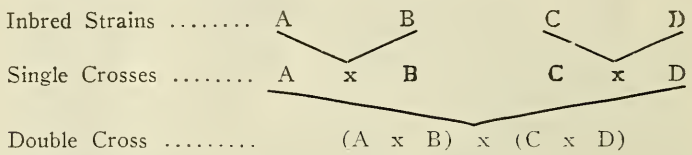
FIG. 24.—All of the ears ripen at the same time.

Inbred strains are also slower in ripening, and the thorough curing, so necessary to insure strong germination, is difficult to obtain.

The success of single crossing will depend very largely on the production of inbred strains which are sufficiently vigorous and productive to make a fair yield of seed. Since corn is being inbred very extensively there is every prospect that such inbred strains will soon be forthcoming and that this method can be used satisfactorily with sweet corn for market gardeners and canners.

DOUBLE CROSSES.

A further development of the method of crossing has been made which overcomes the handicap of low production and poor quality of seed of the first method. This is to cross two first generation hybrids. In this way four different inbred strains are combined by three crossings as follows:



The two crosses of inbred strains are made as described above. The two different lots of crossed seeds are planted in alternating rows in the same way and all the plants of one lot are detasseled in the same way as before. The seed produced on the detasseled plants is used for field planting. The seed from the plants that produced the pollen is of no further value either for field planting or for stock seed and must be discarded.

The two single crosses being vigorous and productive, a good yield of high quality seed is obtained. The crosses produced in this way by one hybrid type pollinated by another are no less productive than either parent and production may even be appreciably increased.

It is important to test the combinations first but when a high yielding and desirable double cross is once produced it can always be reproduced by combining the same strains in the same way.

It is essential that the four inbred strains be of such constitution that they will give good results in all combinations when crossed singly, particularly the crosses AC, AD, BC and BD. The combinations AB and CD should also grow well to give a good yield of seed. The four strains may all come from the same variety or from different varieties. In the latter case the two strains which form the seed parent should come from one variety and the two to form the pollen parent from the other.

Double crosses are not as uniform as single crosses either in height of plant, size and shape of ear, or in time of maturity.

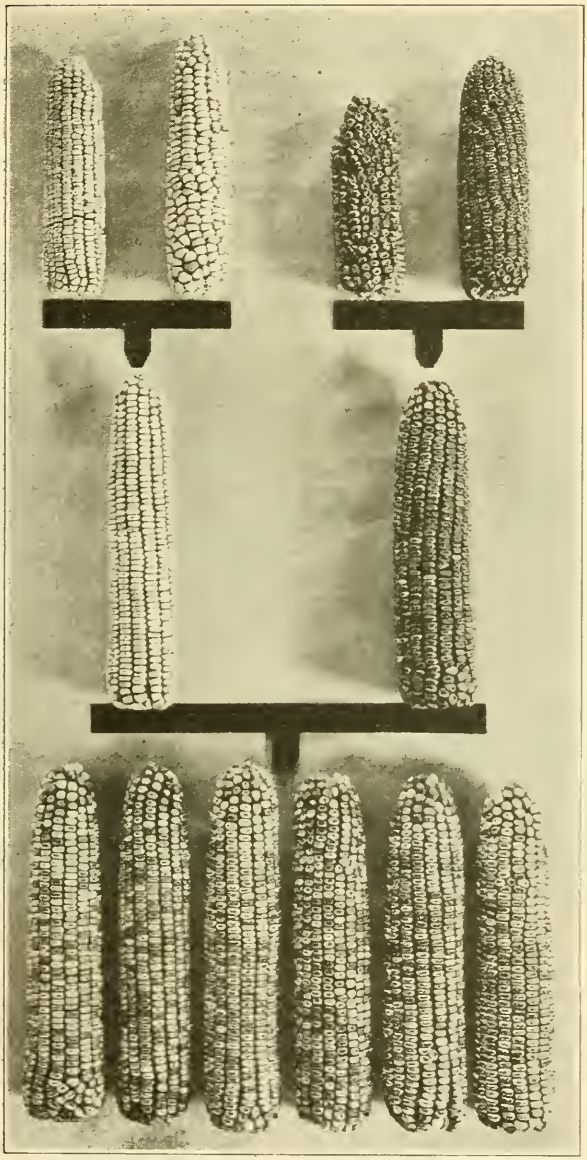


FIG. 25.—Illustrating by actual field results the bringing together of four inbred strains by three crossings to produce double crossed corn.

This is due to the fact that the first generation hybrids used for the seed and pollen parents are all producing ovules and pollen grains of unlike germinal constitution. However, all of the double crossed plants result from hybrid combinations. There is no opportunity for weaknesses to appear due to inbreeding. Hybrid vigor is therefore kept at the maximum and may even be increased. For that reason every plant is strong and sturdy and each one produces a good ear if given an equal chance to grow.

In field corn where uniformity is not so important the greater variability of double crosses may be an advantage in giving the plants a greater adaptiveness to different seasons and soils. All of the plants will not be at the same critical stage of development at some unfavorable period and may escape injury that would seriously damage a more uniform lot of plants.

The productiveness of a double cross compared to the single crosses and the original varieties is shown in the following combination of inbred strains self-fertilized four years, two strains from Century Dent and two from Leaming. Both varieties have been grown for many years in Connecticut, are well adapted to local conditions and are among the highest yielding of all the varieties tested at Mt. Carmel and at Storrs.

Variety or Cross	Yield in Bu. per Acre
Century Dent, 110	47.5
Leaming, 112	44.4
Inbred Century Strain, 110-2	15.3
Inbred Century Strain, 110-4	16.8
Inbred Leaming Strain, 112-1	42.7
Inbred Leaming Strain, 112-4	11.1
Single Cross, 110-2 x 110-4	51.2
Single Cross, 112-1 x 112-4	45.6
Double Cross (110-2 x 110-4) x (112-1 x 112-4).	69.8

The figures represent averages of from two to six plots of each lot. The yields have been corrected for soil differences according to results from the adjoining check plots and all are based on a uniform moisture content of 12 per cent. The double cross gave over 50 per cent more grain than the average of the two parental varieties.

The yield of one of the inbred strains is unusually high, nearly equalling the variety from which it was derived. The quality of the inbred corn was poorer than the variety and this yield was obtained in a field where there was an abundance of pollen. When planted in a separate field and dependent on its own pollen or pollen from another inbred strain it would probably not yield so high.

A combination of two inbred strains of Burr's White Dent and two of Leaming, both varieties originally from Illinois, has been found to give a large and vigorous stalk growth and generally

a higher yield of grain than any variety of corn grown in southern Connecticut. This particular combination is called Double Crossed Burr-Leaming and seed has been grown commercially since 1921. From 1918 to 1922 it was tested at Mt. Carmel in comparison with all of the varieties commonly grown in Connecticut and the yields are given in the first part of this bulletin.

This combination yielded more than all varieties in three out of the five years tested, while no one variety yielded more than

Fig. 26.—Double Crossed Burr-Leaming.

the others in more than one year. The greater return from Burr-Leaming is not only in the larger yield, but also in the freedom from mold, fewer nubbins and less soft corn. In addition the plants have a noticeable ability to stand erect when other varieties are blown down, and show a marked tendency to hold their foliage green until the seeds are ripe.

Although this new kind of corn will not out-yield all varieties, everywhere, in each season, it has been tested sufficiently under farm conditions to show that it can be planted profitably in many places.

Double crosses, like single crosses, will not maintain their high yields more than one year after the cross. From a field of Double Crossed Burr-Leaming that yielded well over one hundred bushels of shelled grain per acre, about one bushel of the largest and finest ears were selected. These were shelled together and this second generation seed was planted the following year in comparison with first generation seed. Two plots averaged 73.5 bushels in comparison with 95.1 bushels for the freshly crossed seed. This is a loss in grain of 23 per cent. The stalks grew vigorously and from the appearance in the field it seemed to be as productive as the first cross but at harvest time it was seen that many plants failed to make a good ear.

MULTIPLE CROSSES.

The principal objection to the method of double crossing is the necessity of maintaining four inbred strains of corn free from outcrossing with each other or other types of corn and making three separate crosses.

Theoretically, the same combinations of factors and in the same proportions can be secured by crossing the second generations from the two single crosses as by crossing the two first generation hybrids. A two years test shows that in the case of the Burr-Leaming combination the second generation of the Burr White single cross by the second generation of the Leaming single cross gives the same yield and quality of corn as the combination of the first generations of those two crosses. The yield and quality of the seed itself produced by second generation plants is not so good but the crop grown from that seed is in every way equal to the combination of the two first generation hybrids.

These results led to "multiple crosses," a further step in the evolution of crossed corn. A number of the best inbred strains of a variety are permanently combined into a fairly uniform type that can be propagated from year to year by natural inter-crossing, as are ordinary varieties. In other words, a "re-created" variety is produced in which all the best of the old variety has been combined and all the inherited abnormalities and weaknesses have been eliminated.

This recreated variety is now crossed with a similar combination of the best inbred strains from some other sort or perhaps a group of inbred strains of different type from the same variety.

Such a multiple cross would have the advantage of producing good yields of well developed seed and crossing each year would give maximum vigor and productiveness. This method has not yet been thoroughly tested but preliminary tests indicate that it will be feasible. The uniformity of the crossed plants produced

by this method may not be as great as in a double cross, but if the right combination of strains is made, yield should be maintained at a high level indefinitely.

MODIFIED SINGLE CROSSES.

Greater uniformity, where this is desirable, can be obtained by combining a number of strains from one line descending from a

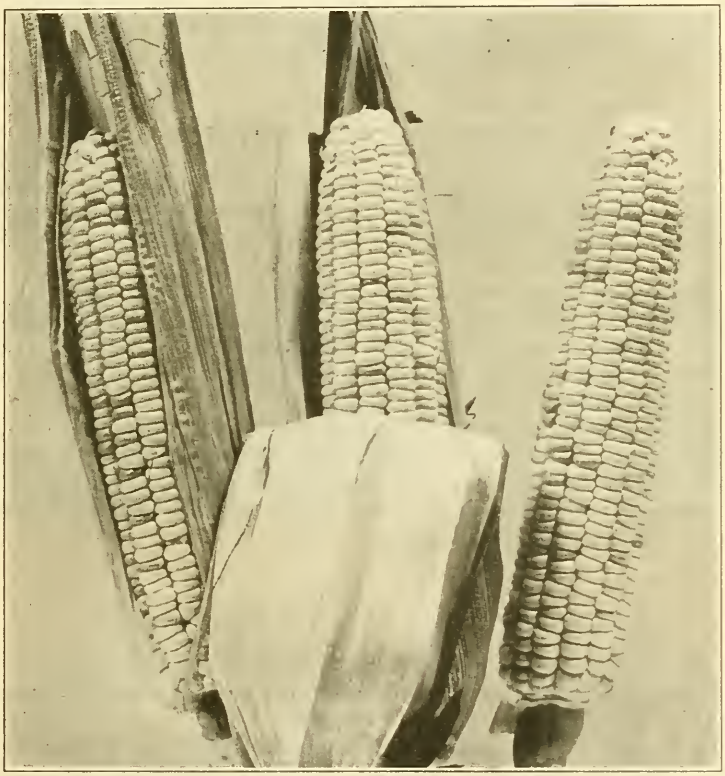


FIG. 27.—The uniform size and shape of ear and even ripening are important factors in sweet corn for market gardening and canning.

single plant but separated in the first or second generation and self-fertilized four or five years to rid them of recessive weaknesses and undesirable characters. Combining several of these sub-strains gives vigor and productiveness closely approaching the original variety and such a combination could be propagated from

year to year by natural inter-pollination, at the same time maintaining a fair degree of fixity of type.

When crossed with a similar combination of sub-strains descending from a different plant of the same or a different variety yield and vigor would be as great as in any system of crossing and the uniformity of the hybrid in certain combinations would be nearly as pronounced as in straight single crosses of two fixed inbred strains.

Crossed seed for field planting would be made each year. The yield and quality of the seed would be better than that produced by single inbred strains and nearly equal in these respects to the method of double or multiple crossing.

UNIFORMITY AND YIELD.

In all of these methods of crossing one must compromise between the uniformity of the crossed corn on the one hand and the vigor and productiveness of the stock strains used in making the cross on the other.

Where uniformity is of great importance it will be best to use the method of crossing two fixed and uniform inbred strains. Where trueness to type is not so important, as in field corn for grain or silage, maximum yields can be obtained, at a lower cost, by double crosses or multiple crosses.

In all systems of crossing inbred strains the variability of the crossed corn is no greater than is now present in all varieties of corn and is frequently less because every plant is vigorous and productive and much poor corn that is usually harvested from every field is largely eliminated.

NECESSITY OF USING CROSSED SEED.

All of these methods of crossing may seem complicated to those who are not familiar with the development of corn breeding practices. It is only necessary to remember, however, that two separate strains of corn must be maintained free from mixing with each other or any other kind of corn and that these two types must be planted in alternating rows and all the plants of one of them detasseled before pollen is shed. The seed produced on these castrated plants is used for planting to produce crossed corn.

The experience of twenty years indicates clearly that the largest yields together with the greatest uniformity and fixity of type adapted to particular requirements can only be obtained by some system of crossing. Furthermore the evidence is conclusive that

these crosses will not maintain their high yields and other desirable qualities in later generations, so that to secure the benefits of hybrid vigor it is necessary to plant crossed seed every year.

COST OF SEED CORN.

It requires about ten bushels of potatoes to plant an acre, about two bushels of oats and a bushel and a half of wheat for a similar area.

Depending upon the size of the kernels and the rate of planting a bushel of corn will plant from four to seven acres. For dent corn five quarts of seed is usually ample for each acre.

While the value of seed corn is somewhat more in proportion to the market value of the grain for corn than other commonly cultivated crops, the cost per acre of the seed is the lowest of the list, and compared to the other expenses of growing a crop of corn, the preparation of the soil, application of fertilizers, frequent cultivation, husking out or cutting up for silage, the cost of the seed becomes almost a negligible item.

For this reason the outlay for seed may be considerably increased, even doubled or tripled, and still be repaid many times over if the high priced seed gives an appreciable increase in yield or improvement in quality.

Crossed corn can do this. It has been tested long enough to show that, when the right combination is obtained, one which is adapted to the locality in which it is to be grown, it will easily pay for the increased cost of the seed, and leave a margin of profit as well.

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